Calibration Service of Radiation Detectors and Dosemeters at IPEN/São Paulo

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Abstract

The Calibration Laboratory of Instituto de Pesquisas Energéticas e Nucleares, IPEN, has already over 25 years been calibrating instruments used in radiation protection and therapy measurements and belonging to hospitals, industries, clinics and other users located in São Paulo and in other parts of Brazil.
At the present time, the Calibration Laboratory is part of the Radiation Metrology Center and it acts in the Radiation Protection, Radiation Therapy, Nuclear Medicine and Diagnostic Radiology areas, using special set-ups with gamma and beta radiation sealed sources, alpha and beta radiation plane sources and low and intermediate energies of X radiation. Moreover, it has reference instruments for each calibration area with traceability to the Brazilian National Laboratory for Metrology of Ionizing Radiation (secondary standards) and international laboratories (primary standards). The number of tested instruments is increasing annually (from 170 in 1980 to 1871 in 2005), and for the development of new techniques and radiation detectors the continuous improvement of the existing calibration methods is necessary, as well as the establishment of new calibration services to be offered by the Calibration Laboratory for Brazilian and South American users. The objective of this study is to show the evolution of the calibration service developed at IPEN, describing the applied methods and the calibrated instruments types. The quality system implantation process following the basis of the NBR IEC/ISO 17025 standard is also presented with some tools used in the calibration procedures.

1. INTRODUCTION

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2. MATERIALS AND METHODS

2.1. Reference Systems

The Calibration Laboratory of IPEN has a specific dosimetric reference system for each radiation quality level. They are listed in Table I. All ionization chambers are connected to a Physikalisch Technische Werkstatten, PTW, UNIDOS electrometer. In the case of alpha and beta radiation, the reference systems are the radioactive sources.

Table I. Dosimetric Reference Systems of the Calibration Laboratory

Radiation level	Ionization Chamber			Traceability
	Type	Manufacturer	Volume (cm^3)	
Radiation protection	Spherical	PTW	1000	PTB*/Germany
Radiation therapy	Thimble	Nuclear Enterprises, NE	0.6	SSDL†/Brazil
	Thimble	PTW	0.6	PTB/Germany
	Plane Parallel	NE	0.03	SSDL/Brazil
Diagnostic radiology-Conventional	Plane parallel	PTW	1	PTB/Germany
	Cylindrical	Radcal	6	SSDL/Brazil
Diagnostic radiology-Mammography	Plane parallel	Radcal	6	FDA‡/USA
Activimeters	Well type	Capintec NPL-CRC	--	NPL§/England

* German Primary Laboratory Physikalisch-Technische Bundesanstalt
† Secondary Standard Dosimetry Laboratory
‡ Food and Drug Administration
§ National Physical Laboratory

2.2 Irradiation Systems

The main characteristics of the gamma and beta irradiation systems utilized for calibration at the Calibration Laboratory of IPEN are described at Tables II and III. The secondary standard beta radiation system is traceable to the German Primary Laboratory PTB. The plane sources of alpha (^{241}Am) and beta radiation (^{14}C; ^{16}Cl; ^{90}Sr+^{90}Y) traceable to the Bureau International des Poids et Mesures (BIPM) are also available to calibrate surface contamination detectors.

Table II. Gamma radiation sources available at the Calibration Laboratory

Source	Energy	Air kerma rates at 1 m (Gy/h)		Reference date
	(keV)	Minimum	Maximum	
^{60}Co	1250	3.8 x 10^{-5}	2.1 x 10^{-3}	23/02/05
^{137}Cs	660	1.92 x 10^{-5}	2.73 x 10^{-2}	22/02/05
		(mGy/min)		
^{60}Co	1250	91.3		21/12/05

Table III. Beta radiation secondary standard system. Reference date : 30/03/06

Source	Energy (keV)	Distance (cm)	Absorbed dose rates (to air) (Gy/h)
^{90}Sr + ^{90}Y	2274	30	3.33x 10^{-3}
		11	1.01
		30	1.38 x 10^{-1}
		50	4.93 x 10^{-2}
^{204}Tl	763	30	8.96 x 10^{-6}
			8.18 x 10^{-5}
^{147}Pm	225	20	1.51 x 10^{-6}
			3.10 x 10^{-5}

The X radiation qualities were established in two different X radiation systems and they are listed in Tables IV, V, VI and VII. Each set of qualities was established according to specific international recommendations. For the radiation protection level, the IEC 4037 standard [1] was followed. For radiation therapy level, the NPL radiation qualities were established, and for diagnostic radiology level the IEC 61267[2] was utilized. For the mammography ionization chambers calibration the NIST qualities were established.

Table IV. Radiation protection level X radiation qualities established at the Seifert/Pantak X radiation system (160 kV).

Radiation Protection Level							
Quality	**Total filtration (mm)**	**Energy (keV)**	**Voltage (kV)**	**HVL (mmAl)**	**Current (mA)**	**Distance (cm)**	**Air kerma rate (Gy/h)**
N60	4 Al + 0.6 Cu	48	60	0.25	20	250	1.99×10^{-2}
N80	4 Al + 2 Cu	65	80	0.612	20	250	1.05×10^{-2}
N100	4 Al + 5 Cu	83	100	1.14	20	250	5.01×10^{-3}
N150	4 Al + 2.5 Sn	118	150	2.4	20	250	4.15×10^{-2}

Table V. Convencional diagnostic radiology level X radiation qualities established at the Seifert/Pantak X radiation system (160 kV).

Quality	**Total filtration (mmAl)**	**Energy (kev)**	**Voltage (kv)**	**HVL (mmAl)**	**Current (mA)**	**Distance (cm)**	**Air kerma rate (mGy/min**
RQR 3	2.5	27.15	50	1.79	10	100	23.21
RQR 5	2.5	30.15	70	2.35	10	100	45.96
RQR 7	2.5	33.05	90	2.95	10	100	72.91
RQR 9	2.5	37.05	120	3.84	10	100	119.88
RQR 10	2.5	40.75	150	4.73	10	100	172.81
RQA 3	2.5+10	37.3	50	3.91	20	100	3.39
RQA 5	2.5+21	49.4	70	6.86	20	100	3.4
RQA 7	2.5+30	59.7	90	9.22	20	100	4.87
RQA 9	2.5+40	71.15	120	11.39	20	100	7.93
RQA10	2.5+45	82.1	150	13.02	20	100	13.28

Table VI. Radiation therapy level X radiation qualities established at the Rigaku Denki X radiation system (60 kV).

Quality	Additional Filtration (mmAl)	Energy (keV)	Voltage (kV)	HVL (mmAl)	Current (mA)	Distance (cm)	Exposure rates (C/kg).h^{-1}
RT25	0.445	14.3	25	0.26	30	50	1.11×10^{-2}
RT30	0.545	15.5	30	0.37	30	50	1.19×10^{-2}
RT40	0.682	17.7	40	0.56	30	50	1.68×10^{-2}
RT45	0.733	18.7	45	0.65	25	50	1.63×10^{-2}
RT50	1.021	21.2	50	0.91	25	50	1.38×10^{-2}

Table VII. Mammography diagnostic radiology level X radiation qualities established at the Rigaku Denki X radiation system (60 kV).

Quality	Total Filtration (mm)	Energy (keV)	Voltage (kV)	HVL (mmAl)	Current (mA)	Distance (cm)	Air kerma rate (mGy/min
M25	0.06 Mo	15.1	25	0.33	30	100	32.9
M28	0.06 Mo	15.3	28	0.34	30	100	39.3
M35	0.06 Mo	16.2	35	0.38	30	100	59.5
M25x	0.06 Mo + 2 Al	18.8	25	0.58	30	100	1.46
M28x	0.06 Mo + 2 Al	19	28	0.61	30	100	2.02
M35x	0.06 Mo + 2 Al	21.6	35	0.85	30	100	4.7

The calibration methodologies applied to the instruments received for the Calibration Laboratory follow the recommendations of the International Atomic Energy Agency [3,4,5].

3. RESULTS

The number of tested instruments is increasing annually (from 170 in 1980 to 1871 in 2005). The Figure 1 shows the evolution of the number of tested instruments from 1989 to 2005. The number of instruments which do not present good conditions for calibration has always been about 20%.

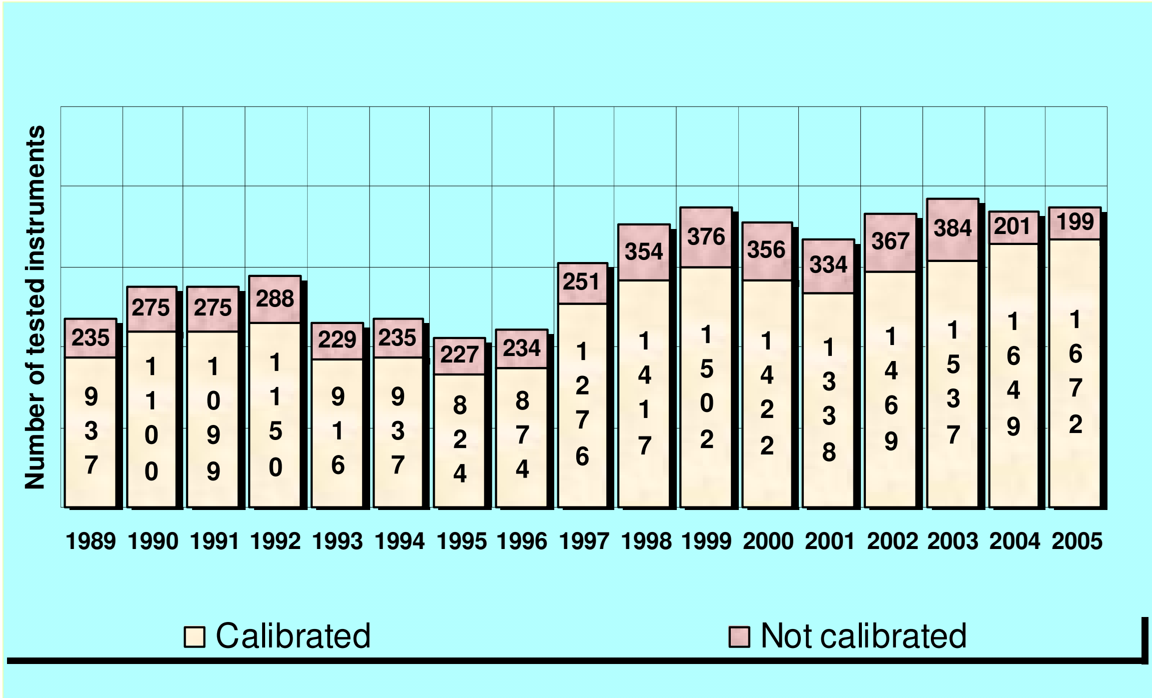

Figure 1. Number of tested instruments from 1989 to 2005 at the Calibration Laboratory of IPEN.

The instruments used in radiation protection measurements represent 88% of the tested instruments by the laboratory annually, 8% are used in diagnostic radiology, 3% in radiation therapy and 1% in nuclear medicine. The Calibration Laboratory has 411 customers divided by the following activities: 39% in the health area (hospitals, clinics, etc), 45% in industries and 16% in the radiation protection services, including IPEN, which is responsible for 14% of all instruments received for calibration.

Figure 2 shows the percentual division of the instruments received for calibration. The instruments used in radiation protection level represent by far the major work of the laboratory.

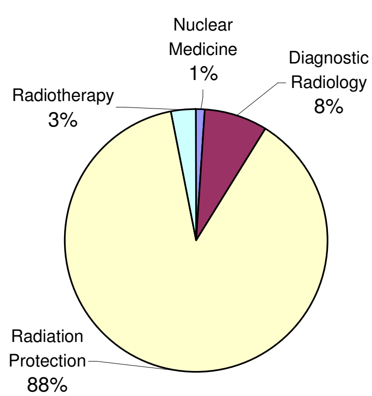

Figure 2. Types of instruments received for calibration.

A quality assurance programme was established at the Calibration Laboratory in 2002, in order to achieve the accreditation of the calibration activities following the requirements of the ABNT ISO/IEC 17025[6]. The quality manual and all procedures, including the uncertainty analysis, are ready. The Calibration Laboratory has undertaken three internal audits and an external audit performed by the Evaluation Committee of the Calibration Laboratories linked to the National Institute of Metrology, Normalization and Industry Quality (INMETRO), Brazil.

The quality assurance system of the LCI follows also the direction lines defined at the Integrated Management System of IPEN, and they can be described by the main characteristics:

Organization and management: The Calibration Laboratory of IPEN is part of the Radiation Metrology Center. The LCI quality assurance programme is coordinated by the Quality Committee of IPEN, the Radiation Metrology Center Manager and the LCI Quality Manager.

LCI quality mission: Calibration of radiation detectors in order to guarantee more accuracy in the radiation measurements and utilization.

Documentation system: It follows the hierarchy shown in Table VIII.

Table VIII. LCI quality assurance system documentation hierarchy

Hierarchic level	Document	Number of documents
Strategic	Integrated Management Manual of IPEN, MGI-IPN	01
	Quality Manual , MQ-CMR	01
	Business plan, PN-CMR	01
Tactician	Action plan, PA-CMR	01
	IPEN Management procedures, PG-IPN	08
	CMR Management procedures, PG-CMR	06
Operational	Operational procedures, PO-LCI	16
	Technical Instructions, IT-LCI	10

4. CONCLUSIONS

The number of tested instruments annually shows the needs for the development of new techniques and radiation detectors. The continuous improvement of the existing calibration methods is necessary, as well as the establishment of new calibration services to be offered by the Calibration Laboratory for Brazilian and South American users, as well as the implementation of a quality control system, which will facilitate the management of the internal procedures and their improvement.

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REFERENCES

1. ISO 4037-1:1996; "X and Gamma Reference Radiations for Calibrating Dosimeters and Dose ratemeters and for Determining Their Response as a Function of Photon Energy", International Organization for Standardization, 1996
2 ISO/IEC 61267, “Medical diagnostic X-ray equipment - Radiation conditions for use in the determination of characteristics”. Second Edition 2005.
3. IAEA SRS 16. “Calibration of Radiation Protection Monitoring Instruments”, International Atomic Energy Agency, Vienna, 2000
4 IAEA TRS 374, “Calibration of Dosimeters Used in Radiotherapy”, Technical Report Series no. 374, International Atomic Energy Agency, Vienna, 1994
5 IAEA TRS 398, “Absorbed Dose Determination in External Beam Radiotherapy: An International Code of Practice for Dosimetry based on Standards of Absorbed Dose do Water, International Atomic Energy Agency, Vienna, 2000.
6 Brazilian Association of Technical Standards, 2005. Requisitos Gerais para a Competência de Laboratórios de Calibração e de Ensaios, ABNT NBR ISO/IEC 17025, 2005. (Brazilian version of the Standard ISO/IEC 17025) (In Portuguese).